BOTANICAL ECOLOGY AND CONSERVATION OF THE LAGUNA DE LA HERRERA (SABANA DE BOGOTA, COLOMBIA)

V.M. WIJNINGA
Hugo de Vries-laboratorio, Kruislaan 318, 1098 SM Amsterdam, Holanda.

ORLANDO RANGEL
Instituto de Ciencias Naturales, Museo de Historia Natural, A.A. 7495, Bogotá D.E., Colombia.

A.M. CLEEF
Hugo de Vries-laboratorio, Kruislaan 318, 1098 SM Amsterdam, Holanda.

Resumen
Se estudió la vegetación alrededor de la Laguna de La Herrera, una laguna andina a 2550 m. Se diferenciaron una comunidad de *Phytolacca bogotensis* (1): comunidades helofíticas dominadas por: *Scirpus californicus* y *Typha angustifolia* (2); *Scirpus californicus* (3); *Polygonum punctatum* (4); *Rumex obtusifolius* y *Polygonum punctatum* (5); *Bidens laevis* (6); *Hydrocotyle ranunculoides* (7); comunidades pleustofíticas con: *Limnobium laevigatum*; (8); *Azolla filiculoides* y *Lemna* cf. *gibba* (9) y *Eichhornia crassipes* (10). Se registraron la estructura, composición florística, los rasgos ecólogicos y la distribución de las comunidades y se comparó con la conductividad eléctrica y la calidad del agua. Finalmente, se hacen recomendaciones para la conservación de la laguna y la vegetación acuática.

Abstract
The acuatic, helophytic and pleustophytic vegetation of the Laguna de La Herrera, on the southwestern border of the high plain of Bogotá at 2550 m was studied following the Zurich-Montpellier approach. The communities recognized were: terrestrial community of *Phytolacca bogotensis*; helophytic communities of *Scirpus californicus* and *Typha angustifolia* ; *Scirpus californicus* ; *Polygonum punctatum* ; *Rumex obtusifolius* with *Polygonum punctatum* ; *Bidens laevis* ; *Hydrocotyle ranunculoides*. Pleustophytic communities of *Limnobium laevigatum* ; *Azolla filiculoides* with *Lemna* cf. *gibba* and *Eichornia crassipes.* The structure, floristic composition and ecological aspects were also considered. Several recommendations about conservation of the Laguna are given.

Introduction

Laguna de La Herrera lies on the southwestern border of the high plain of Bogotá at an altitude of approximately 2550 m in the Cordillera Oriental of Colombia. Its origin is probably due to fluvial erosion, perhaps by the old course of the river Bojacá (Van der Hammen & Parada, 1958). The surface of the lake is about 2.9km^2. As a result of its location the lake lies in the rainshadow of the hills, which surround the lake at the southside. The effect of the low annual precipitation, and the relatively high evapotranspiration, determines the main feature of the area. These hills are therefore covered by a semi-xerophytic vegetation, which consists mainly of *Opuntia* spp., *Furcraea* cf. *humboldtii* and shrubs of *Dodonaea viscosa* and *Eupatorium leivense* (Vink & Wijninga, 1988). Data for the annual and monthly precipitation, temperature and evapotranspiration are obtained of two metereostations. The first is Tibaitatá, at a distance of about 7km of the lake; the second one is located on the property of hacienda Casa Blanca at 2km of the lake. Both stations are property of HIMAT. Precipitation: mean annual rate is 635 mm and its distribution over the year is bi-modal. The rains are distributed from april to june and from september till november. Temperature: the average is 12.5°C. Occassionally nightfrosts occur. Evapotranspiration: average annual rate of 1068 mm. Considering the mean annual precipitation, an annual waterdeficit exists of approximately 430 mm.

Laguna de La Herrera is the last remaining big natural lake on the high plain of Bogotá. Up till now few studies were made of lake vegetations in the andean vegetation belt (2300m-3500m) in the Northern Andes. Recent vegetational studies of lakes in this belt were made of Lago de Tota (Boyacá, 3000m) by Rangel & Aguirre (1983) and of Laguna de Fúquene (Cundinamarca, 2550m) by Cleef & Salamanca (in prep.) and some additional observations by Rangel (in prep.).

The study of the current succession of tropical mountain lake vegetation is important for the interpretation and better understanding of the vegetational history and dynamics stages of the former lake of Bogotá (Hooghiemstra, 1984) and the former vegetation of the lake itself (Van der Hammen & González, 1965).

This study aims also to be a contribution to a protected status for Laguna de La Herrera by INDERENA (Instituto Nacional de los Recursos Naturales Renovables y del Ambiente).

Material and methods

Fieldwork in Colombia was carried out in 1985 by the first author and R. Vink. The relevés were taken according to the Zürich-Montpellier approach. The relevé areas (1, 4, 9, 16 m²) were chosen depending on the complexity and structure of the vegetation communities (Table 1A). Of all the aquatic communities distinguished, lifeforms were determined and also structure diagrams (profile sketch and surface drawings) were made (Figs. 1-10). The arrangement of the relevés in the synoptic table was based upon similarities in floristics between the seperate relevés.

Watersamples have been taken twice at the same place, and in two different seasons to determine the chemical content and to detect differences between the various sites in the lake and between the same sites in time (Table 1B). Further pH and ECC (Electric Conductivity Capacity) have been determined for all aquatic communities (Table 2A). For the elaboration of the vegetation map of the lake (Fig. 11) true color aerial photographs, taken by Aereofotogramétrica Andina Limitada in january 1985. The plant species found in the lake specimens were collected in duplo. The specimens were determined and stored in the Herbario Nacional of the Universidad Nacional in Bogotá (COL) under the collection numbers of V. Wijninga & R. Vink. One set of species will be sent to the State University of Utrecht (The Netherlands). For the complete species list see Vink & Wijninga (1988).

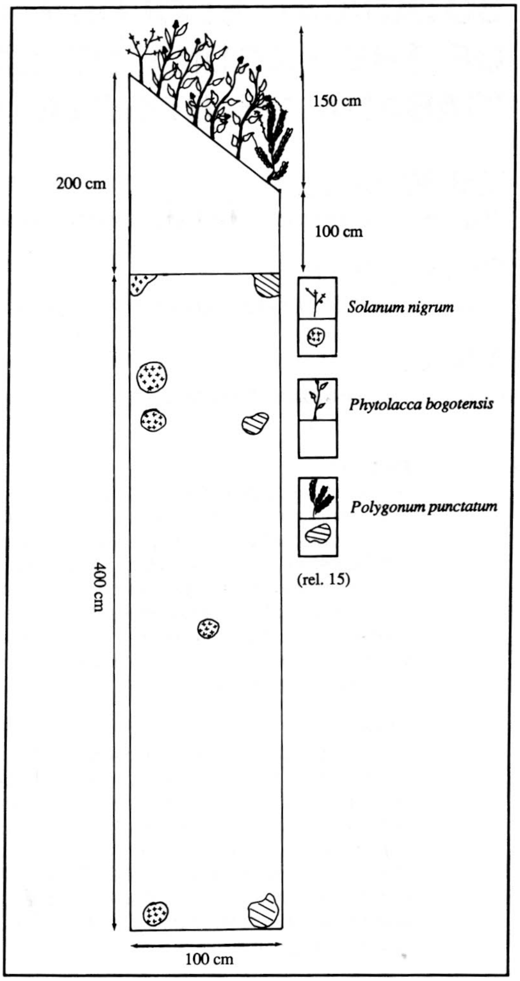

Figura 1. Vegetation community of *Phytolacca bogotensis*

Description of the azonal vegetation communities

THE TERRESTRIAL COMMUNITY OF *PHYTOLACCA BOGOTENSIS* (fig. 1)

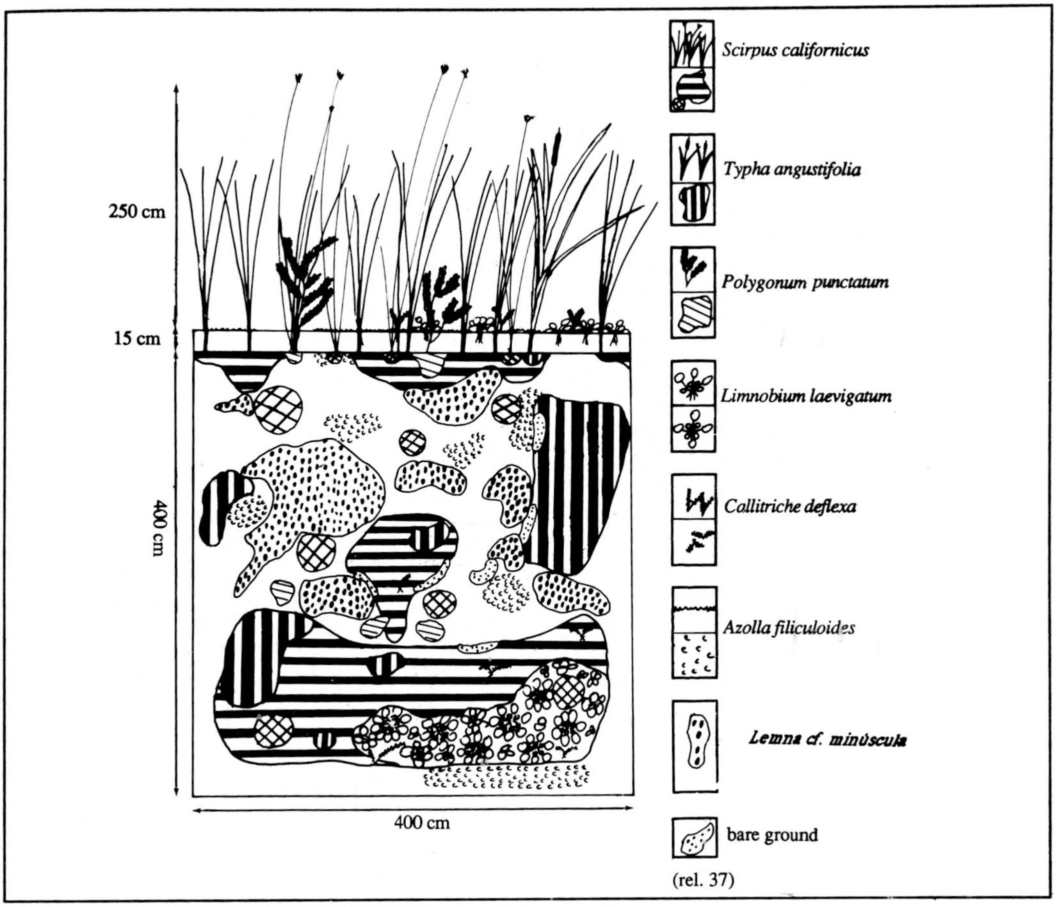
250 cm
15 cm
400 cm
400 cm
Scirpus californicus
Typha angustifolia
Polygonum punctatum
Limnobium laevigatum
Callitriche deflexa
Azolla filiculoides
Lemna cf. minúscula
bare ground
(rel. 37)

Figura 2. Vegetation community of *Scirpus californicus* and *Typha angustifolia*.

PHYSIOGNOMY: forms dense stands, and only one stratum could be distinguished. The height of this herb layer varies between 40 to 75cm. The total vegetation cover is between 90% and 98%.

COMPOSITION: the dominating species is *Phytolacca bogotensis*. The characteristic species are *Solanum nigrum* and *Ludwigia peruviana*.

SYNECOLOGY: this community was situated above the waterline along one of the dikes around the lake. In the literature *Phytolacca bogotensis* is mentioned as an indicator of disturbance. It may be that this community also occurs at some places like in Lago de Tota (Rangel & Aguirre, 1976) where it grows around cultivated land and on burned areas in the páramo of Monserrate (Vargas & Zuluaga, 1985), where *Phytolacca bogotensis* is an 'invader'. In the Cordillera Central it is common to see large stands dominated by *Phytolacca bogotensis* after fire.

HELOPHYTIC COMMUNITIES

COMMUNITY OF *SCIRPUS CALIFORNICUS* AND *TYPHA ANGUSTIFOLIA* (Fig. 2)

PHYSIOGNOMY: is determined by the high *Scirpus californicus* and *Typha angustifolia* plants and also by the leaf-bearing *Scirpus californicus* plants. A division could be made of the herb layer in a low and high herb layer. The high herb layer (height 250 cm)

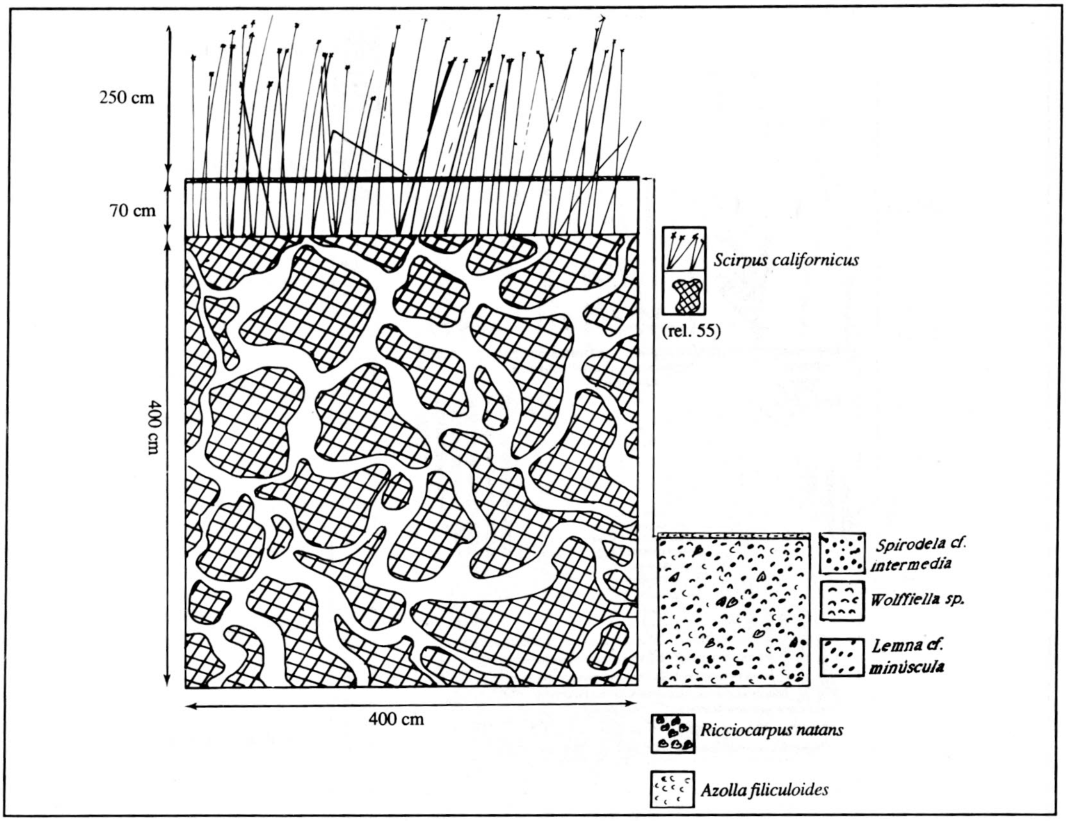

Figura 3. Vegetation community of *Scirpus californicus*

covers 60% and the low herb layer 4% (height 30 cm). The cover of the floating layer was 22% (height 3 cm).

COMPOSITION: Are present 5 helophytic and accompanied at the time of censing by 4 pleustophytic species. *Scirpus californicus*, as sterile specimens and therefore provided with leaves, is dominant. *Typha angustifolia* is the characteristic species. Further are recorded *Callitriche deflexa*, *Polygonum punctatum*, all with low percentages. The following pleustophytic species have also been found: *Lemna* sp., *Limnobium laevigatum*, *Azolla filiculoides* and *Ricciocarpus natans*, all with moderate to low percentages.

SYNECOLOGY: the average waterdepth was 15 cm. However small parts of the subtratum were emerged (+5cm). On these parts *Callitriche deflexa* and plant number 97 were growing. The pH was around 6 and the average EEC value was 130 µS. No clear explanation is known, why *Scirpus californicus* plants occur here only sterile. This community, which covers around 50m^2 is found at the southeast side of the lake.

COMMUNITY OF *SCIRPUS CALIFORNICUS* (Fig. 3)

PHYSIOGNOMY: *Scirpus californicus* species determines the physiognomy of this community. The high herb layer only consists of *Scirpus californicus* specimens. Its height and cover range from 200 cm to 250 cm and from 40% to 85%, respectively. A low herb-layer has been recorded only once (height 30cm and coverage 5%). Further the floating vegetation (height 1cm) is prominent. It forms a dense mat which cover varies between 85% and 95%.

COMPOSITION: *Scirpus californicus*, here fertile specimens only, is the dominating helo-

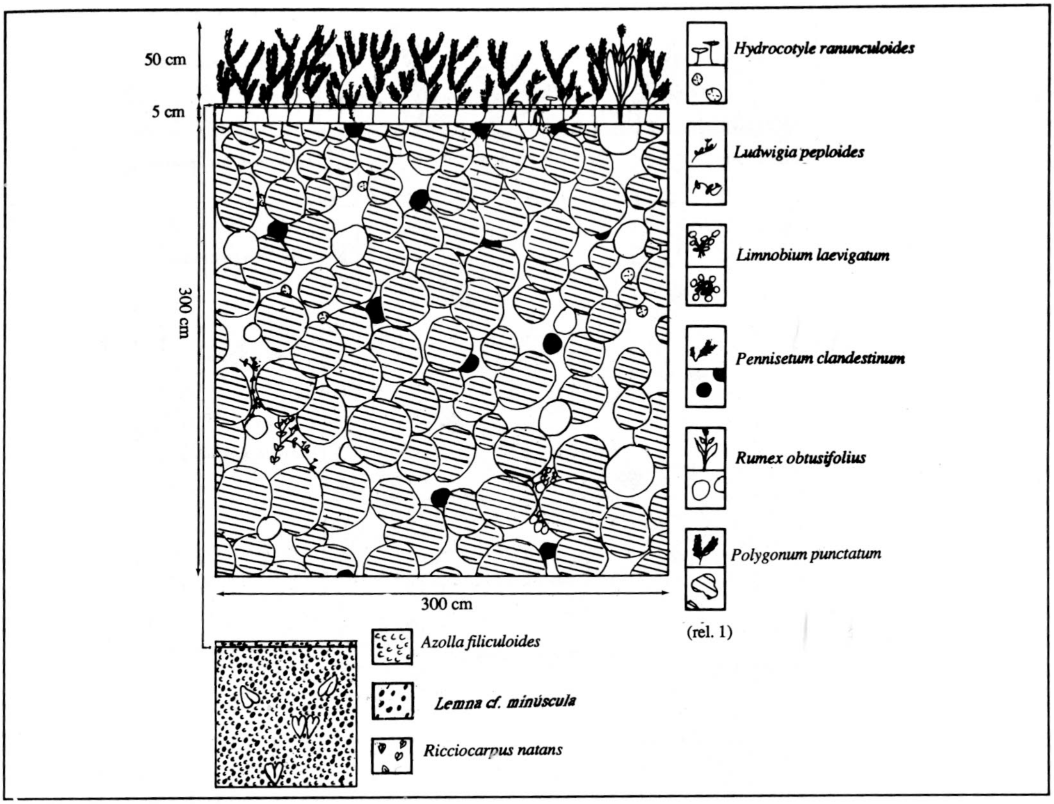
50 cm
5 cm
300 cm
300 cm
Hydrocotyle ranunculoides
Ludwigia peploides
Limnobium laevigatum
Pennisetum clandestinum
Rumex obtusifolius
Polygonum punctatum
(rel. 1)
Azolla filiculoides
Lemna cf. minuscula
Ricciocarpus natans

Figura 4. Vegetation community of *Polygonum punctatum*

phytic species. In one relevé two other species are associated namely *Polygonum punctatum* and *Rumex obtusifolius*. Of the floating plants *Lemna* sp., is present with moderate coverages and almost entirely restricted to this community. *Lemna* cf. *gibba* occurred only in two relevés with high cover percentages. Both *Azolla filiculoides* and *Ricciocarpus natans* are present throughout this community.

SYNECOLOGY: the waterdepth varies between 40 and 150cm. The pH ranges from 5.8 to 6.0. The ECC values recorded are relatively low (average 95 µS). Recently Rangel (in prep.) sampled stands of *Scirpus californicus* vegetation in Lago la Cocha in southwestern Colombia. Among the associated species there were: *Polygonum punctatum*, *Rumex obtusifolius*, *Carex* sp., *Relbunium ciliatum*, and species of *Ranunculus* and *Lachemilla*. This community covers 21 % of the total area of the lake.

COMMUNITY OF *POLYGONUM PUNCTATUM*

(Fig. 4)

PHYSIOGNOMY: the physiognomy of this community is determined by the *Polygonum punctatum*. Together with other herbs, it forms one herb-layer with a height varying from 25 cm to 80 cm. Its cover ranges from 45% to 80% (average: 70%). The cover of the floating layer is mostly very high. Only in one relevé the cover was 3%. The range is from 3% to 95% (average: 82%). The height varies from 1 to 5 cm. The total vegetation cover lies between 65% and 100% (average: 96%).

COMPOSITION: the dominant species is *Polygonum punctatum*. The associate species is *Hydrocotyle ranunculoides*. Further occur infrequently *Rumex obtusifolius*, *Ludwigia peploides* and *Pennisetum clandestinum*, all with low cover values. Of the pleustophytic species *Ricciocarpus natans*, *Azolla filiculoides* and *Lemna* cf. *gibba* have been re-

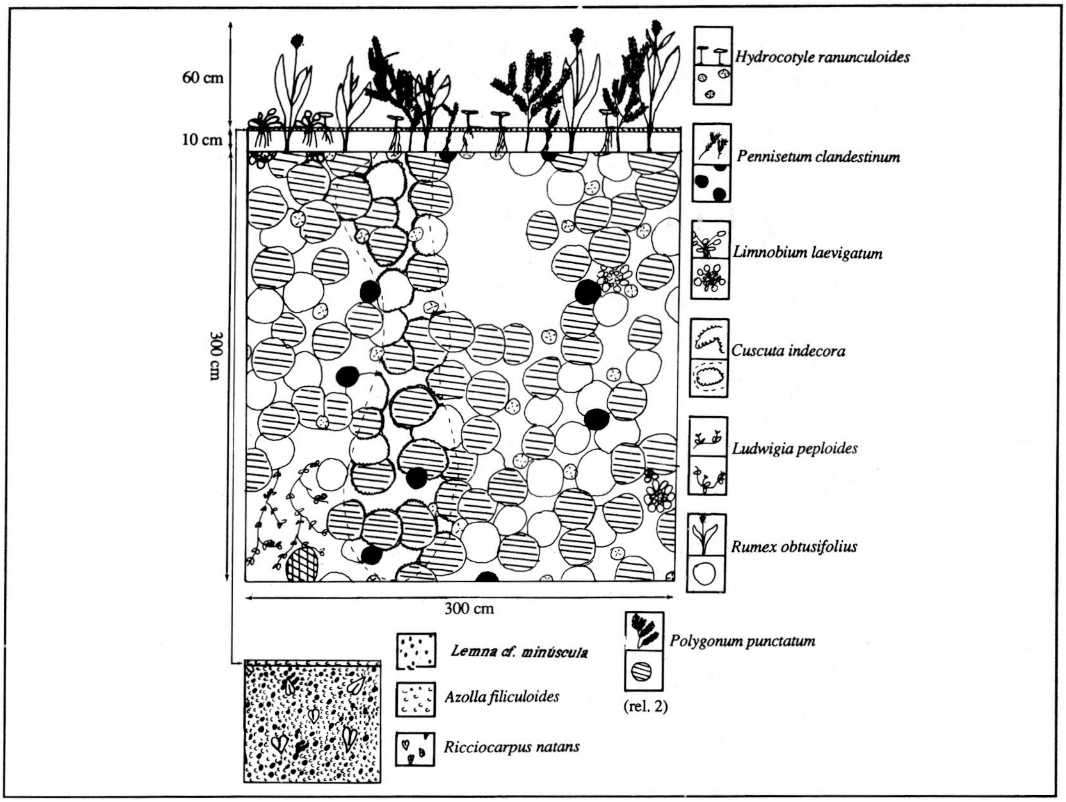
60 cm
10 cm
300 cm
300 cm
Hydrocotyle ranunculoides
Pennisetum clandestinum
Limnobium laevigatum
Cuscuta indecora
Ludwigia peploides
Rumex obtusifolius
Polygonum punctatum
(rel. 2)
Lemna cf. minúscula
Azolla filiculoides
Ricciocarpus natans

Figura 5. Vegetation community of *Rumex obtusifolius* and *Polygonum punctatum*.

corded. Occassionally *Limnobium laevigatum* was found.

SYNECOLOGY: the waterdepth varies between 5 cm and 60 cm. The pH range is quite large (5.8 to 6.8). The average ECC was 187 µS. This community occupies frequently zones along the marshy shores and it is not found in the central area of the lake. It covers 14 % of the total area of the lake.

COMMUNITY OF *RUMEX OBTUSIFOLIUS* AND *POLYGONUM PUNCTATUM* (Fig. 5)

PHYSIOGNOMY: the dominant *Rumex obtusifolius* species, ocassionally together with *Polygonum punctatum*, principally determines the physiognomy of this vegetation community. They mainly determine the herb layer (height 35 cm to 55 cm) with a cover from 25% to 60%. The floating layer is well developed with covers ranging from 60% to 100%. The height of this layer varies between 1cm and 5 cm. The total vegetation cover is between 80% and 100%.

COMPOSITION: the compostion of this community has some similarities with the previous described community of *Polygonum punctatum*. Except that the dominant species is *Rumex obtusifolius* and *Polygonum punctatum* is the accompanying species. Other taxa present are *Epilobium denticulatum*, *Lilaeopsis* cf. *schaffneriana*, and *Vazquezia* cf. *anemonifolia*. These last three species were found on a floating mat of half decomposed plant remains. Accompanying species are *Pennisetum clandestinum*, *Ludwigia peploides* and *Hydrocotyle ranunculoides*. The following pleustophytic species have been recorded: *Ricciocarpus natans*, *Limnobium laevigatum*, *Azolla filiculoides* and *Lemna* cf. *gibba*.

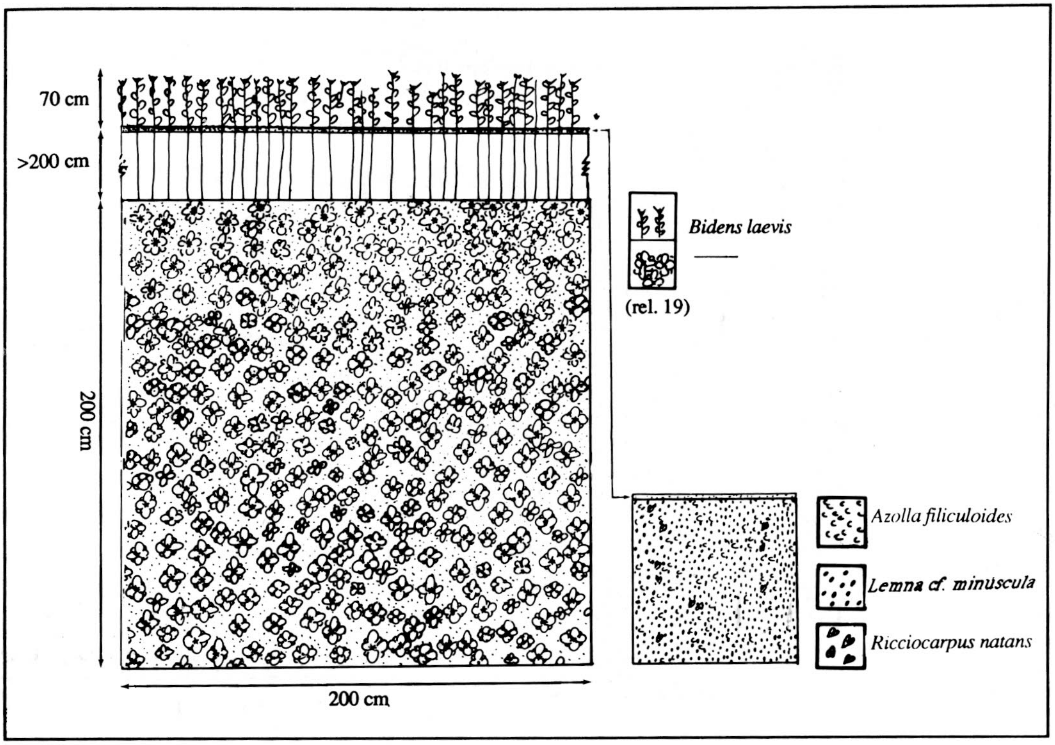

Figura 6. Vegetation community of *Bidens laevis*.

SYNECOLOGY: the range of the waterdepth recorded for this vegetation community is between +5cm and -80cm. The range for both pH and ECC is low. The average pH is 6 and average EEC is 108µS. It is found somewhat north of the central part and further in isolated parts all over the lake. The community of *Rumex obtusifolius* and *Polygonum punctatum* covers 21 % of the total area of the lake.

COMMUNITY OF *BIDENS LAEVIS*

(Fig. 6)

PHYSIOGNOMY: almost pure and dense stands of *Bidens laevis* plants determine the physiognomy of this plant community. The cover is between 75% and 100% and the height varies from 35 cm to 50 cm.

The cover of the floating layer is very irregular, ranging from 5% to 95 %. The height varies between 1 cm and 5 cm. The total vegetation cover is very high: from 98% to 100%.

COMPOSITION: the dominant species is *Bidens laevis*. Associate species is *Hydrocotyle ranunculoides*, which has been recorded several times with moderate covers. Furthermore *Ludwigia peploides* and *Rumex obtusifolius* were only found in two relevés, both with a very low cover. The pleustophytic species *Limnobium laevigatum* is often well represented. Remarkable is the almost total absence of *Azolla filiculoides*. *Lemna* cf. *gibba* is in six of the seven relevés present with low to moderate coverages. *Ricciocarpus natans* is found only once.

SYNECOLOGY: this community is in general restricted to the northside of the lake and in particularly to the course of the river Bojacá. The waterdepth varies from 180 cm to more as 200 cm. The pH ranges from 5.9 to 6.1. The ECC values are relatively high (average 208 µS). It may be clear that this community has a preference for habitats of deeper water and is therefore not widely distributed. The absence of a well developed floating layer might

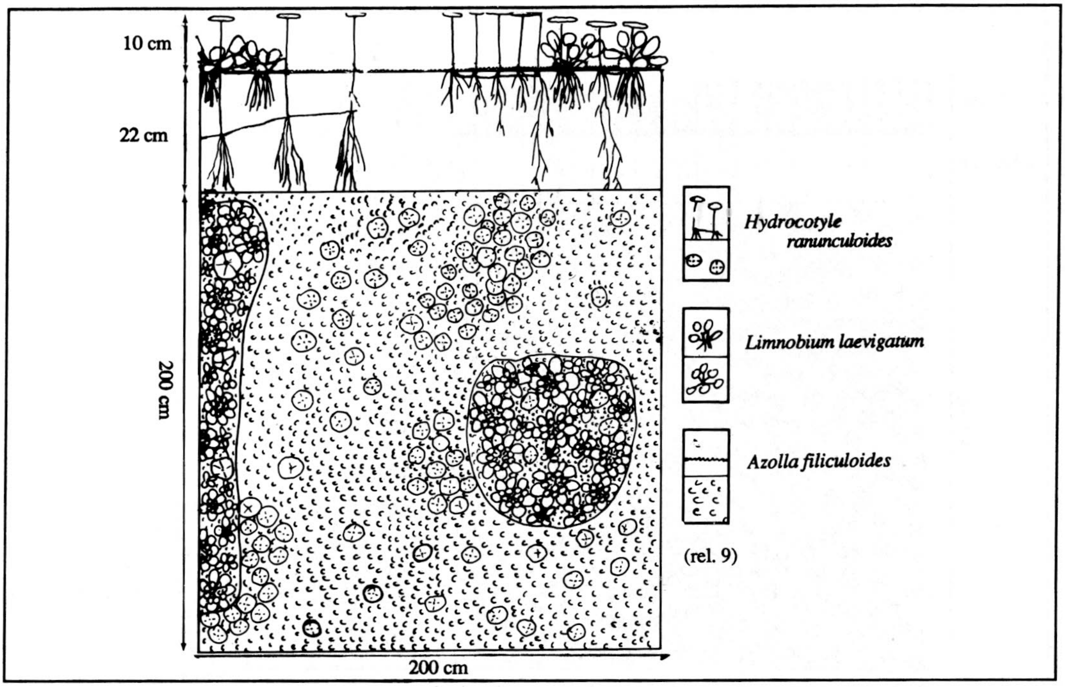

Figura 7. Vegetation community of *Hydrocotyle ranunculoides*.

be related to the occurrence of water currents at the sites where this community was found and the dense helophytic vegetation.

COMMUNITY OF *HYDROCOTYLE RANUNCULOIDES* (FIG. 7)

PHYSIOGNOMY: the physiognomy of this community is principally determined by the relative low *Hydrocotyle ranunculoides* plants. A herb layer is almost absent, only in one relevé a low herb layer was found with a cover of less than 1% and a height of 10 cm. The floating layer is well developed, its cover ranges from 75% to 100% and the height varies from 2 cm to 5 cm.

COMPOSITION: the characteristic species is *Hydrocotyle ranunculoides*. It has a moderate to high cover. Other species are: *Pennisetum clandestinum*, recorded twice and *Ludwigia peploides*, recorded only once, both with a low cover. Of the pleustophytic representatives *Azolla filiculoides* is dominant with a moderate to high cover. *Lemna* cf. *gibba* is represented with low covers and even absent in one relevé. Three species are only found once: *Lemna* sp., *Ricciocarpus natans* and *Limnobium laevigatum* of which only the latter reaches a moderate cover.

SYNECOLOGY: the waterdepth is from -40 cm to +2cm. Nor pH or ECC values show a large range. The values for the first are between 5.9 and 6.2 and for the latter between 98 and 113 µS. It is found only in small parts in the north and northwest side of the lake. It covers a limited area of the total lake: 1%.

PLEUSTOPHYTIC COMMUNITIES

COMMUNITY OF *LIMNOBIUM LAEVIGATUM* (Fig. 8)

PHYSIOGNOMY: the dominant species is *Limnobium laevigatum*. The low herb layer is very poorly developed. The cover of this layer reaches 2% and the height ranges from 11cm to 35cm. The floating layer forms a dense cover varying from 75% to 100%. Its height ranges from 1cm to 5 cm. The total vegetation cover varies between 75% to 100%.

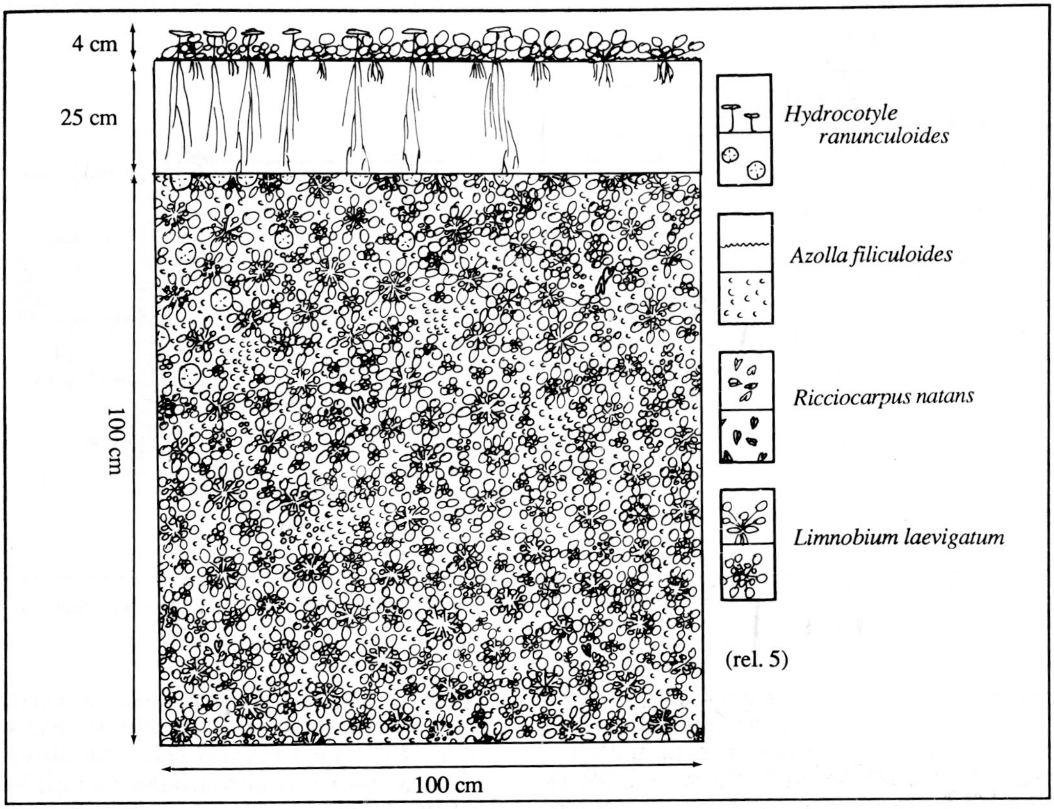

Figura 8. Vegetation community of *Limnobium laevigatum*.

COMPOSITION: in this community *Limnobium laevigatum* is the dominant species. It reaches moderate to high cover percentages. Only two other pleustophytic species are common in this community, namely *Azolla filiculoides* and *Lemna* cf. *gibba*, with sparse to moderate coverages. *Ricciocarpus natans* is recorded once. The helophytic species are scarcely present.

SYNECOLOGY: the waterdepth varies between 2 cm and 200 cm. The pH range is moderate: 5.6 to 6.4. The range of the EEC values is small: 92 to 118 µS. This community covers large areas of the lake. A large zone at the southside is occupied with this community. Further smaller areas are occupied near the shores and other parts of the lake. It covers 25 % of the total area of the lake.

Community of *Azolla filiculoides* and *Lemna* cf.*gibba* (Fig. 9)

PHYSIOGNOMY: the floating mats of *Azolla filiculoides* define the physiognomy of this community. A herb layer is totally absent. The very well developed floating layer has a cover, which reaches from 90% to 100%. The height of this layer is more or less constant: 1-2 cm.

COMPOSITION: the dominant species in this community is mainly *Azolla filiculoides*, which forms dense floating mats. The floating layer is the only one present and is very well developed. In most cases *Azolla filiculoides* reaches high to very high covers. *Lemna* cf. *gibba* is the characteristic species and has mostly a low to moderate cover percentage. In one relevé *Lemna* cf. *gibba* is absent, but *Lemna* sp., was found instead with a moderate cover. Besides these species *Ricciocarpus natans* and *Limnobium laevigatum* are infrequently recorded, both with low cover percentages.

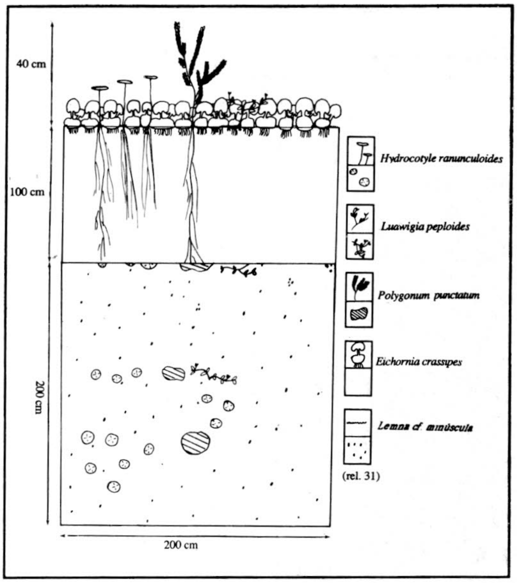
40 cm
100 cm
200 cm
200 cm
Hydrocotyle ranunculoides
Luawigia peploides
Polygonum punctatum
Eichornia crassipes
Lemna cf. minúscula
(rel. 31)

Figura 9. Vegetation community of *Azolla filiculoides* and *Lemna* cf. *gibba*.

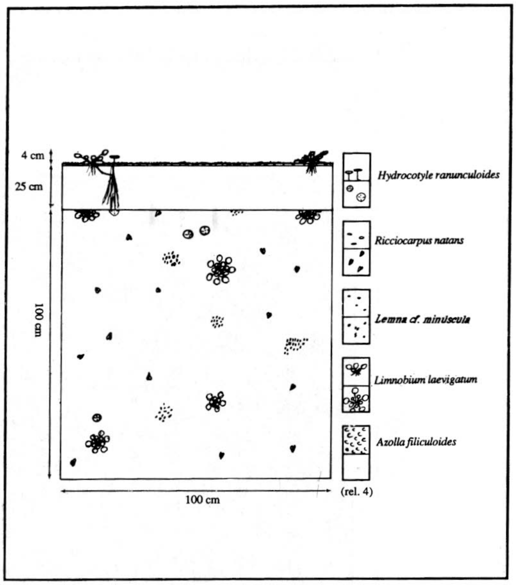
4 cm
25 cm
100 cm
100 cm
Hydrocotyle ranunculoides
Ricciocarpus natans
Lemna cf. minúscula
Limnobium laevigatum
Azolla filiculoides
(rel. 4)

Figura 10. Vegetation community of *Eichhornia crassipes*.

SYNECOLOGY: the waterdepth ranges from 15 cm to 40 cm. The ranges of pH and EEC are both large. For the first a range is recorded of 5.9 to 6.9 and for the second 108 to 550 µS. At certain sites it occupies considerable areas, but mostly it covers smaller areas near the shores of the lake. It covers 14% of the total area of the lake.

Community of *Eichhornia crassipes* (Fig. 10)

PHYSIOGNOMY: the almost monotypic stands of the charcteristic *Eichhornia crassipes* plants determines the physiognomy of this community. The low herb layer covers between 98% and 100 % and the height varies between 15 cm and 30 cm. The floating layer is poorly developed and mostly absent. When present it covers 2% to 10%. The height is between 1 cm and 2 cm. The total vegetation cover is very high: 99% to 100 %.

COMPOSITION: the dominant species of this community is *Eichhornia crassipes*. because it forms such dense stands hardly any other species have been recorded. The ones that have been found, are representatives of the pleustophytic species *Azolla filiculoides*, *Lemna* cf. *gibba* and *Spirodela* sp. From the *'in situ'* rooting species have been recorded: *Polygonum punctatum*, *Ludwigia peploides* and *Hydrocotyle ranunculoides*. All three with very low cover percentages and all in the same relevé.

SYNECOLOGY: the waterdepth varies between 10 cm and 200 cm. Average ECC and pH values are respectively 147µS and 5.9 with moderate ranges. The occurence in the Laguna de La Herrera is limited (only present in the northwest point of the lake). This species is a common weed in the tropical lowlands. It causes there big troubles, because of its rapid growth rate (Gaudet, 1974). In Colombia it is introduced in lakes at much higher elevation e.g. Laguna de La Herrera and Laguna de Fúquene. A less rapid growth of *Eichhornia crassipes* at these altitudes can be assigned to lower average daily temperatures and the sometimes occurring nightfrosts. No flowering specimens have been observed in both lakes.

Distribution of the vegetation communities

The detailed vegetation map (see Fig. 11) based upon true color aerial photographs was made, to show the distribution of the dif-

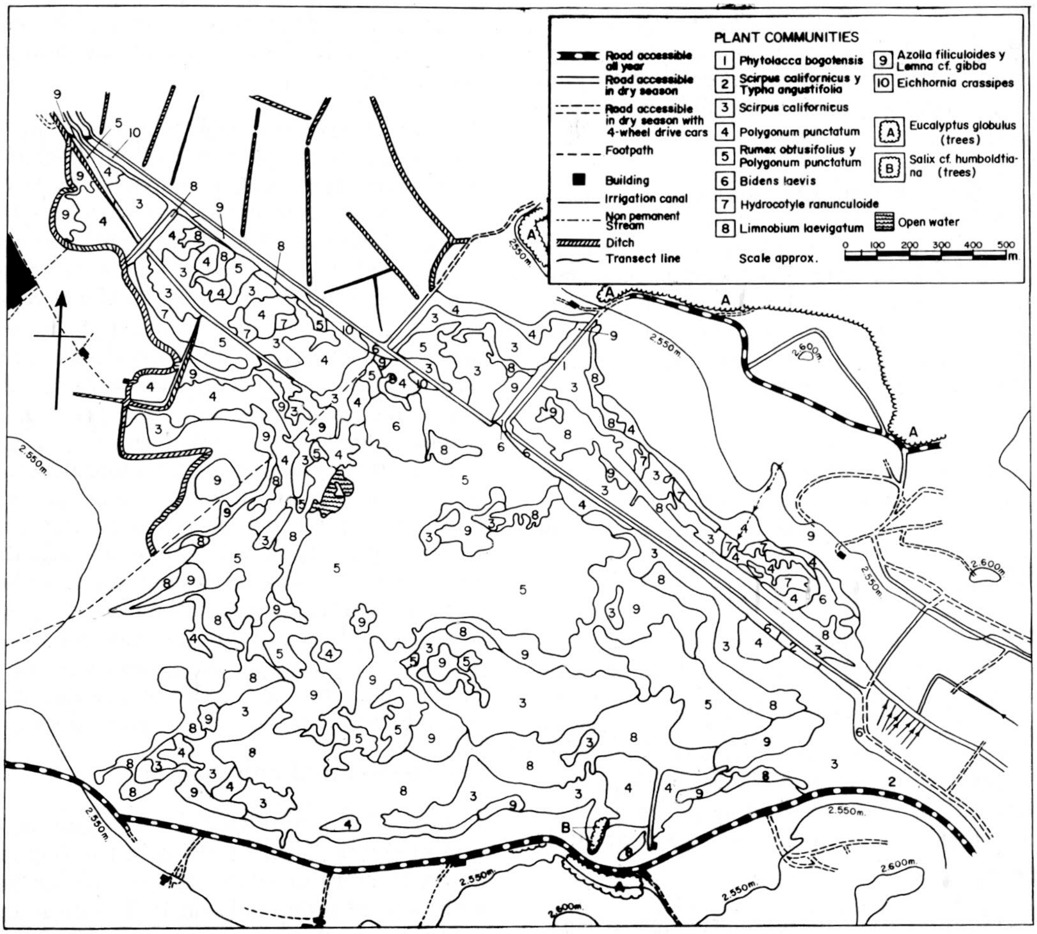
PLANT COMMUNITIES
Road accessible all year
Road accessible in dry season
Road accessible in dry season with 4-wheel drive cars
Footpath
Building
Irrigation canal
Non pemanent Stream
Ditch
Transect line
1 Phytolacca bogotensis
2 Scirpus californicus y Typha angustifolia
3 Scirpus californicus
4 Polygonum punctatum
5 Rumex obtusifolius y Polygonum punctatum
6 Bidens laevis
7 Hydrocotyle ranunculoide
8 Limnobium laevigatum
9 Azolla filiculoides y Lemna cf. gibba
10 Eichhornia crassipes
A Eucalyptus globulus (trees)
B Salix cf. humboldtiana (trees)
Open water
Scale approx.
0 100 200 300 400 500 m
2.550m.
2.600m.

Figura 11. Vegetation map of Laguna de la Herrera.

ferent vegetation communities in Laguna de La Herrera. These photographs had a scale of 1:8000 and were taken in january 1985. With the aid of these photographs a provisional photointerpretation map was made. After a field check the map was reinterpretated and subsequently the final map was drawn on a topographical map (nr. 227-4-A-4; 1:10.000; 1978). The vegetational part of the legenda reflects the hierarchical order of the vegetation communities according to the synoptic table.

Impact on the lake vegetation

The area where the Laguna de La Herrera is situated, has principally an agricultural destination. Several haciendas and small houses are located in the vicinity of the lake. The human impact on the lake vegetation is evident and works in a direct and indirect way.

In the following part the influences of man and livestock on the lake vegetation will be discussed somewhat more in detail.

Direct influences:
1. cutting of the reed by man
2. cattle feeding on waterplants

1) In the near past, people living around the lake have been cutting reed (*Scirpus californicus*). The reed was used as construction material (e.g. for roof cover, mats) and as food for cattle (Aguirre and Rangel, 1976;

Ramírez & Beck, 1981). The traces of the reed cutting are still visible today on aerial photographs as small canals through the reed vegetation. No recent reed cutting has been observed during the fieldwork in the lake.

2) From the vegetation map can be observed that the lake is almost completely surrounded by pastures, where cattle grazes. Cattle can walk freely into the lake, because no fence is present at the lake side. Several times it was seen that cattle was standing in 1 meter deep water, feeding on the water plants (mainly *Limnobium laevigatum*).

Indirect influences :
1. the claiming of land
2a. wateruse by farmers and
2b. the change of the lake into a waterreservoir
3. waterpollution

1) A serious impact on the lake is the claiming of parts of the lake. A comparison of aerial photographs taken in 1957 with the ones from 1985, showed that small parts of the lake were open water or covered by aquatic vegetation in the past. These parts are now dry milled and are used as pastures. They are concentrated in the northwest part of the lake.

2a) In this semi-arid region the need of water for irrigation is quite big. Normally farmers pomp the water out the lake, while others use the water from the river Bojacá. This results in a drop of the water level, especially during the dry season. But the decreasing waterquality of the lake during the last years forced the farmers to find new ways to forfill their need for water.

2b) The recent plan of the Corporación Autonoma Regional (C.A.R.) to turn the lake in to a water reservoir must be seen in the view of point 2a. In this way the presence of a sufficient water supply for irrigation will be secured for the future. But such a plan will have its consequences for the lake and its flora and fauna. Some are the constructions that will be made to achieve a larger watercapacity of the lake and the subsequent rise of the water level; the quality of the water to be pomped in the lake (this water will be drained of the river Bogotá north of Bogotá); and the likely destruction of the aquatic vegetation.

3) Several irrigation canals are present on the borders of the pastures at the northside of the lake. The water transported by these canals, which are connected with the Rio Bojacá, flows over the slooping pastures and subsequently in the lake. The water from these irrigation canals were locally covered with a thick foam layer, indicating the presence of detergents. The river, thus containing the same nutrients as the water in the irrigation canals, is therefore principally responsible for the poor waterquality in the lake. Further the degradation and destruction of the vegetation will increase erosion and causing an increase of sediment rich water streaming in the lake, especially during the heavy rains in the wet season. Other forms of pollution include the dung dropped by cattle in the water and the observed use of artifical fertilizers on the grasslands. Both cause a increase of nutrients streaming in the lake either by run off- or groundwater.

Discussion and conclusions

In total 25 different species (belonging to 16 families) have been recorded in the Laguna de La Herrera in 1985. Of these 25 species eight are recorded only once. The most important recorded species can be divided in the five different lifeforms: helophyta, reptohelophyta, pleustohelophyta, lemnids and riccielids (Scultphorpe, 1967 and Bloemendaal *et al.*, 1988). Although there is a dominance of helophytic communities in the lake, the lemnid species cover the larger part of the lake. This due to the overlap of the helophytic and pleustophytic species, because the latter forms floating layers under the helophytic plants. The constant presence of pleustophytic species seems to be the main cause for the absence of submerged species, because of the interception of light and the hampering of the gas exchange at the water surface (for example a low O_2 concentration in the water). Open water areas are further scarse and small sized.

From the synoptic table ten different plant communities could be distinguished. The division was based upon differences in floristics and lifeforms. One terrestric community, 6 'in situ' rooting communities and 3 pleustophytic communities have been distinguished. The *helophytic* species are diagnostic for the communities they represent. Most pleustophytic species are faithfull and show a considerable rate of tolerance, but their optimum is represented by higher vegetation cover than in less favorable conditions (e.g. under helophytic species).

The nutrient content of the water samples (see Table 1B) shows relatively large differences in place and time. No clear relation exists between the nutrient content of the samples on the one side and time and the different sites in the lake on the other side. It shows further high potassium and phosphate values. Although a comparision of these values with a classification system for the determination of the eutrophy level (Roelofs & Bloemendaal, 1988) reveals that the amount of nutrients is moderate, a substantial part of the nutrients is stored in the waterplants. This part is not represented in the table. Because of the excessive plantcover the actual eutrophy level is therefore higher.

The presence of heavy metals in the lake bottom is not automatically poisonous to living organisms. It is there availability, which is important whether they are poisonous or not. This availability depends largely on how the metals are influenced by the physical and chemical circumstances in the waterbody. Such circumstances can either mobilise or immobilise them. In general heavy metals are less poisonous for plants than for animals, mainly because the former has a bigger storage capacity (Bloemendal & Roelofs,1988). Therefore their influence on the aquatic vegetation in Laguna de La Herrera is likely to be small. Although the concentration of heavy metals (Table 2B) is relatively low (compared with dutch standars: Lagas,1987), small waterorganisms tend to accumulate such metals in their bodies. As they are at the beginning of the food chain, the ultimate effects for birds and others aquatic animals preying on them, may be more severe.

Coesel (in prep.),who took an algae sample in Laguna de La Herrera, showed that the combined occurence of the algae species (*Staurodesmus dejectus, Staurodesmus lobatus, Eudorina* and *Volvox*) that point to a moderate waterquality and species *(Euglena, Phacus and Trachelomonas)* that point to organic pollution, indicates a less stable environment and may be the result of a contact zone between these two waterqualities. This means that local differences in water quality exist and also strong fluctuations of waterchemistry in time. An explanation herefore could be that the sample was taken at the southside of the lake where cattle often walk in the lake and drop their dung in the water. The pH and ECC values of water samples (Table 2A) taken in the lake, range from 5.5 to 6.9 and from 85 to 550 µS, respectively. The pH range is not very large, but the ECC values show large differences. This too could be related with the relatively large local differences in nutrient content. The absolute ECC values are low. But these values do not show the real amount of anions and cations, because of a partial storage in the waterplants. Other ecological factors such as fluctuations of the water level, waterdepth, wave action, substratum and light are hardly of any importance for this lake and do not contribute substantially to the abiotic diversity of the lake. The fluctuation of the water level in the lake is principally determined by the season. During the dry season the water is most of the time stagnant, where during the rainy season the surplus of water is streaming out of the lake. This causes a fluctuation in water level between the two seasons of about 20 cm to 30 cm. The waterdepth of the lake is limited, namely less than 2.5 m . The agitation as well as the light are factors of less importance. Due to the dense vegetation cover hardly any agitation occurs and it prevents light to penetrate the deeper water levels. The substratum is probably uniformous: grey muddy clay and provides therefore only one type of rooting medium for the helophytic species.

A clear hydrosere is lacking in Laguna de La Herrera. The distribution of the plant communities follows more a mosaic pattern. Several causes such as the shallow depth, the dense vegetation cover and the subsequent lack of wave action and submerged species, the lack of different substrata and the disturbance of the aquatic vegetation by cattle can be attributed for this absence.

The relative abundance of helophytic species is an indication that the succession is already in an advanced stage. Gaudet (1974) stated that emergent macrophytes, especially reed plants, are common in shallow lakes, where the filling process is obviously in progress. These macrophytes are efficient in trapping silt from land run-off and river deposits. Waterbodies in the final stages of silting up (the last stage of succession), like this lake, reedswamps are usually present. Also the presence of so many other helophytic species in Laguna de La Herrera point in this direction. The vegetational succession in the future seems that first the pleustophytic species (with their leaves, the photosynthetic organs, nearest to the water surface) will be replaced by the *'in situ'* rooting species, because of the decreasing waterdepth as a result of the silting up of the lake and the competition for light. This would mean that first the lemnids and ricciellids than the pleustohelophytic and at last the helophytic species will disappear. However, the pleustohelophyta, lemnids and ricciellid plants may 'survive' for a longer time in the floating vegetation layer of the helophytic communities.

The history of the lake vegetation (Van der Hammen & González, 1965) showed that some, nowadays disappeared, species were present (like *Potamogeton* and *Myriophyllum*), which represent two other lifeforms. The absence of submerged and other life forms is likely to be caused by the dense vegetation cover. this is in its turn the result of the relatively high eutrophy level. A lower eutrophy level and the removal of the larger part of the free floating waterplants would contribute to a more optimal biological diversity in the lake.

Recommendations

The aquatic vegetation and fauna of Laguna de La Herrera is rather unique for the high plain of Bogotá. Preserving this small, but unequalled, area and protecting it against human influences gives the opportunity for the survival of its flora and fauna on the high plain of Bogotá with its expanding urbanisation and also the opportunity for a continous study of the succession of the aquatic communities. This protecting status should be given by INDERENA, an institute which administrates more reserves and national parks in Colombia.

Together with the protecting status, also a number of measures must be taken in order to secure and improve the life condition of the fauna and flora in this lake. The most important measure would be the improvement of the waterquality. The major waterinlet comes from the river Bojacá. Its waterquality is poor and being a constant source of excessive nutrient input for the lake. The improvement of the river water will subsequently improve the waterquality of the lake. Further cattle must be prevented to enter the lake and the use of artificial fertilizers restricted. As the eutrophy level has been lowered, the excessive growth of the free floating plants can be dealed with. A good solution might be the mecanical removal of the larger part of these plants, thus creating again open water areas. The partly removal of the free floating plants will, by the way, lower too the amount of nutrients in the lake. *Eichhornia crassipes* should be removed completely, because it is an introduced species. It will be likely that the free floating plants have to be removed for several successive years. Before they are removed the waterplants should be examined on their heavy metal content. If they contain heavy metals, the plants should not be stored on or near the shores of the lake, but taken away to a refuse dump. The removal of the waterplants will result in a higher O_2 concentration in the water and a possible return of submerged species. A rich vegetation community contributes also to a better waterquality. A side effect may be that also representatives of the aquatic fauna can make there reappearence in the lake, resulting in a enrichement of the fauna. This means that the biological diversity would increase. But the removal of the floating vegetation must be done carefully in order not to disturb the avifauna, which largely depends on this aquatic vegetation.

The use of water out of the lake should be more controlled. Because a considerable drop

PARAMETERS: / COMMUNITIES:	average total cover %	number of strata	average number of species	releve area m²	average waterdepth cm	waterdepth range cm		% of lake surface	pH (mean)	E.C.C. µs (mean)
						max.	min.			
Phytolacca bogotensis	95	2	3	4	+115	+150	+50	<1	--	--
Scirpus californicus & Typha angustifolia	95	3	9	16	-15	X	X	<1	6.0	130
Scirpus californicus	100	3	6	16	-69	-150	-40	21	5.9	95
Polygonum punctatum	96	3	6	9	-39	-60	-5	14	6.2	187
Rumex obtusifolius & Polygonum punctatum	96	2	6	9	-40	-80	+5	21	6.0	108
Bidens laevis	99	2	4	4	-196	200	-180	3	6.0	208
Hidrocotyle ranunculoides	94	2	4	4	-22	-40	+2	1	6.0	106
Limnobium laevigatum	96	2	4	1	-37	-200	-3	25	5.9	104
Azolla filiculoides & Lemna cf. minuscula	98	1	3	1	-27	-40	-15	14	6.1	249
Eichhornia crassipes	100	2	2	4	-53	-200	-10	<1	5.9	147

A

Date	Nr.	P in PO4	P-tot.	N in NO3	NNo2	N in NH4	SO4	Cl	Ca	Na	K	Fe	Mg	Mn	Cu
Mar 28, 1985	1	0.24	0.25	0.04	<0.01	1.45	7.5	11	5.7	9.5	3.5	<1	1.4	<0.1	<0.1
Mar 28, 1985	2	0.04	0.04	0.04	<0.01	0.16	2.0	2.0	9.2	14.0	9.4	<1	3.1	0.2	<0.1
Mar 28, 1985	3	0.03	0.04	0.04	<0.01	0.18	6.5	13	3.8	10.0	3.0	<1	1.7	<0.1	<0.1
Mar 28, 1985	4	0.23	0.28	0.06	<0.01	0.10	10.5	62	19.0	64.0	13.0	1	8.7	0.3	<0.1
Mar 28, 1985	5	0.03	0.05	0.04	<0.01	0.06	8.0	16	5.1	14.0	3.8	<1	2.3	<0.1	<0.1
Mar 28, 1985	6	1.70	1.80	0.02	<0.01	0.03	25.0	20	12.1	18.5	8.0	13	5.2	0.4	<0.1
Mar 28, 1985	7	0.15	0.17	0.02	<0.01	1.00	8.0	11	5.0	8.5	3.4	<1	1.4	<0.1	<0.1
Mar 28, 1985	8	0.04	0.09	0.14	<0.01	0.25	10.5	18	5.5	18.0	2.5	2	2.8	<0.1	<0.1
Jul 2, 1985	9	0.03	0.32	1.21	0.19	3.20	7.0	24	8.9	25	5.4	<1	2.5	--	--
Jul 2, 1985	10	0.43	0.45	0.02	0.01	2.10	12.0	17	8.4	18	4.7	2	2.8	--	--
Jul 2, 1985	11	0.35	0.54	0.01	0.02	2.30	7.0	19	90	18	9.5	7	3.5	--	--
Jul 2, 1985	12	1.58	1.85	7.50	<0.01	<0.50	20.0	29	25.0	45	14.0	7	11	--	--
Jul 2, 1985	13	1.05	1.40	1.70	<0.01	<0.50	25.0	30	16.0	28	13.0	11	77	--	--
Jul 2, 1985	14	0.29	0.31	0.11	0.01	<0.50	13.0	18	7.3	21	4.1	<1	2.5	--	--
Jul 2, 1985	15	0.42	0.43	2.29	0.01	<0.50	13.0	17	7.6	18	4.4	<1	2.8	--	--
Jul 2, 1985	16	1.37	1.58	0.01	0.01	0.7	43.0	40	17.0	45	6.8	22	6	--	--

B

Tabla 1. A. Survey of some ecological parameters B. Nutrient content of the water samples (Values in PPM)

A.

Community	pH	ECC (μS·cm^{-1})
Scirpus californicus & *Typha angustifolia*	6.1	139
	5.9	121
Scirpus californicus	6.0	99
	6.0	88
	5.8	100
Polygonum punctatum	6.8	360
	5.8	105
	5.8	97
Rumex obtusifolius & *Polygonum punctatum*	6.0	139
	6.0	121
	5.9	99
Bidens laevis	6.1	221
	6.0	114
	5.9	290
Hydrocotyle ranunculoides	6.2	107
	6.0	113
	5.9	98
Limnobium laevigatum	6.4	118
	5.8	92
	5.6	102
Azolla filiculoides & *Lemna* cf. *minuscula*	6.9	550
	5.9	108
	5.9	290
Eichhornia crassipes	6.1	225
	6.0	86
	5.6	130

B.

	Locality	Pb	Zn	Cd	Cu
1	North-Western	21	155	2,9	8,5
2	Middle-Zone	52	31	0,5	8,6
3	North-Zone	36	56	0,4	11
4	Witness-Value Dutch-standards	50	200	1,0	50

Table 2. A. The pH and ECC values for each aquatic communitiy. B. Amount of heavy metals (values in ppm) in some analysed samples from the lake bottom. Dutch standards are also given for this metal (Lagas, 1987). Sample with amounts below this values are considered as no polluted.

of the water level, especially during the dry season, will occur. This will affect the marginal vegetation of the lake. If the plan of the C.A.R. proceeds to turn Laguna de La Herrera in a water reservoir, its flora and fauna could be in danger. Although details of this plan are not known, considerable impacts on the lake vegetation are obvious. So the water used for filling the reservoir will be pomped out the polluted Bogotá river. Further larger and bigger water level changes can be expected, affecting the helophytic plants.

The reed cutting by the local people was not noticed during our fieldwork. But if this is still practised today it must be controlled or stopped. It is known that cutted reed needs a certain time to recover, so excessive cutting can destroy the *Scirpus californicus* vegetation.

The illegal claiming of some areas of the lake must be prevented. The lake itself is already small and the fact that still parts are or will be claimed is a threat to the lake. The C.A.R., who is responsible for the lake, should try to get these areas back and even let them make part of the lake again.

The heavy metals (especially Pb) in the lake bottom are a major threat to the livestock and the people in the area. It should be recommended to prevent the contact of livestock and people with the water of the lake. Such can be achieved by the construction of a fence around the lake and not to use the water for drinking and irrigation purposes. The cause of the heavy metal pollution in the lake must be found, so that proper measurements can be taken to prevent further accumulation in the lake. It is further recommended to investigate the water itself to find out in which way the metalic elements are present as free elements.

But it may be clear from the above that a more thorough study to the environmental effects of this plan of the different forms of pollution on the flora and fauna and the management of the lake is needed, because up till now no such study has been completed. Especially, because this lake provides not only a shelter for the aquatic vegetation but also for its quite rich avifauna. Also a continuing study of the aquatic vegetation provides the opportunity to follow the different plant-communities in time and can offer there fore data for a better interpretation of the succession of the local vegetation in palynological studies.

Acknowledgements

We wish to express our regards to drs. J. Aguirre-C. for his support during our fieldwork . For the determination of the numerous higher plants we thank, dr. S. Diaz, dr. G. Lozano, dr. R. Jaramillo and drs. P. Franco. The first author expresses his gratitude to dr P. Ruíz, director of the Instituto de Ciencias Naturales of the Universidad Nacional for his hospitality during his stay in the Herbario Nacional and the necessary arrangements and to all the other employees of the Herbario Nacional for their generous cooperation. We thank dr. J.C. Lindeman of the State University of Utrecht for the final determination of a number of collected plants. We want to thank mr R. Bregman and mrs A. Philip for the analyses of the watersamples. Further we thank mr S. Fernández for the drawing of the vegetation map. We are grateful to the University of Amsterdam and the Treub-maatschappij for the financial support to the first author.

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